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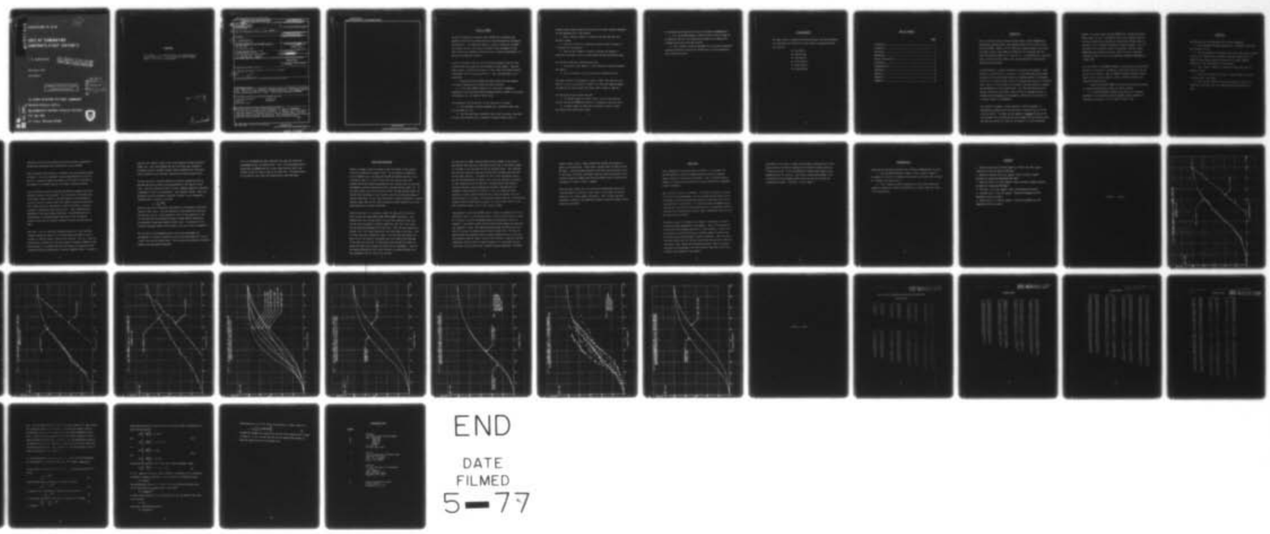

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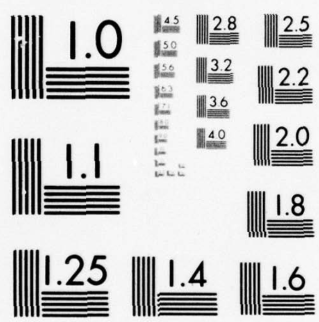

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USAAVSCOM TR 76-44

COST OF TERMINATING CONTRACTS STUDY (COTCOS-1)

J. S. Sutterfield

November 1976

Final Report

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US ARMY AVIATION SYSTEMS COMMAND
Systems Analysis Office
Developmental Systems Analysis Division
P.O. Box 209
St. Louis, Missouri 63166

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REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER: USAAVSCOM TR-76-44
2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle): Cost of Terminating Contracts Study (COTCOS-I)
5. TYPE OF REPORT & PERIOD COVERED
6. PERFORMING ORG. REPORT NUMBER: DRSAV-D-76-10
7. AUTHOR(s): J. S. SUTTERFIELD
8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Systems Analysis Office, AVSCOM DRSAV-DD, P.O. Box 209, St. Louis, MO 63166
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 44 p.
11. CONTROLLING OFFICE NAME AND ADDRESS: Systems Analysis Office, U.S. Army Aviation Systems Command, P.O. Box 209 ATTN: DRSAV-DD, St. Louis, Missouri 63166
12. REPORT DATE: Nov[redacted]76
13. NUMBER OF PAGES
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)
15. SECURITY CLASS. (of this report): UNCLASSIFIED
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

Final rept.,

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

This report prepared in cooperation with Directorate for Production and Procurement. Results of study presented at DARCOM Headquarters on 28 October 1976 and study approach approved for all MSCs. Study results approved for AVSCOM.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Termination Liability
Curve Fit
Regression Curve
Correlation
Statistics

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This study had as its object the development of a curve of termination liability for use on Army aircraft contracts. An "equally likely" or average curve was graphically developed from five sets of contract data. From this graphical curve an equation was developed. This equation provided an analytical curve that almost perfectly reproduced the original graphical curve.

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EXECUTIVE SUMMARY

The Cost of Terminating Contracts Study (COTCOS) was initiated at the request of the Aircraft Systems Division of the Directorate for Procurement and Production. The request was made as a result of concern as to whether the progress payments being made by foreign military purchasers of Army type aircraft were adequate to defray the cost of contract termination; i.e., defray the termination liability.

A set of termination liability tables had been developed by the Air Force and were being recommended for use throughout the DOD complex. There was doubt, however, regarding the adequacy of these tables for foreign military transactions involving Army type aircraft. Thus, the objectives of the study were:

1. Determining whether DARCOM information would have been adequate for several representative airframe and spares contracts.

2. In the event DARCOM information was found to be inadequate, developing a curve that would provide adequate progress payments in 50 percent of the cases, i.e., an "equally likely" curve.

The assumptions forming the basis for the study were as follows:

1. That government furnished equipment has a negligible effect upon the incurrence of cost.

2. That the reporting of cumulative costs "lags" the actual incurrence of costs; this reporting lag is assumed to increase linearly until it

reaches 90 days midway through the contract and to remain constant thereafter for the remaining half of the contract.

3. That a "normal" contract is closed out 90 days after the last delivery is made.

4. That cost incurred in a continuous function, when in reality it is discrete and discontinuous.

5. That the small number of contracts available for analysis is sufficient to provide a basis for sound generalizations about future cases.

The following conditions constrained the study:

1. A relatively small number of "clean contracts" on which to perform the analysis.

2. Lack of uniformity in the incurrence and reporting of costs.

The study resulted in the average or "equally likely" cost incurred curve shown in Figure 10, page 26 and the equation for the curve shown on page 36. The equation was used to obtain the values shown in Table I, page 28.

The conclusions from the study were that:

1. The AVSCOM average or "equally likely" curve of cost incurred fulfills the current DARCOM definition for a termination liability curve.

2. A greater number of cases must be analyzed in order to render the analysis more statistically sound.

The foregoing conclusions gave rise to the following recommendations:

1. That the AVSCOM average or "equally likely" curve of Figure 10 be adopted as the basis for reckoning the payments to be made by FMS customers who purchase Army type aircraft.

2. That a computer system be developed for using future contractual reporting information to modify the AVSCOM curve as may be required to make it more descriptive.

ACKNOWLEDGEMENTS

The author wishes to thank the following personnel from the Directorate for Procurement and Production for their help and cooperation during this analysis:

Mr. Don Schmitz

Mr. Richard Kurtz

Mr. John McMillan

Ms. Mildred Bynum

Ms. Marge Sherrill

Ms. Diane Mayfield

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INTRODUCTION

Prior to 1973 the volume of foreign military sales in which USAAVSCOM was involved was relatively small; the combined volume for FY 71 and FY 72 was less than $100M. However, in FY 73 there was a sharp increase in the volume of foreign military sales (FMS); the volume for FY 73 was more than five times the combined volume for FY 71 and FY 72. In anticipation of a continuing large volume of foreign military sales, the Directorate for International Logistics was established.

Each FMS requires a schedule of payments to be made by the customer. These payments are used to defray a percentage of those costs that were estimated as going to be incurred during the 90 days following receipt of the payment. Prior to FY 73, when the dollar volume of foreign military sales was relatively small, there was little concern as to whether or not the schedule of payments was representative of the incurred costs. But with the increasing dollar volume of foreign military sales, there has been an attendant increase in concern about the adequacy of the payments to defray the incurred costs of a contract should it be terminated.

This schedule of payments, called termination liability payments, is constructed by supposing that the contractor's incurred costs will follow a certain profile. The amount of each payment is <u>normally</u> the sum of the cost estimated to be incurred 90 days after payment and the estimated amount that would be required to "clean-up" the contract if it were terminated.

However, in a recent letter from the DARCOM Plans, Systems and Analysis Office, page 2 of Incl 1, termination liability was defined to be just the costs estimated to be incurred by the contractor 90 days hence; no allowance is to be included for possible "clean-up" charges. Incl 2 of the above letter contained a table of termination liability figures. DARCOM MSCs were directed to use this table of values in computing termination liability in all sales agreements undertaken subsequent to 1 August 1976.

Prior to receipt of the DARCOM information, Systems Analysis Office (SAO) had been in the process of validating a termination liability curve for use on aircraft systems. When the DARCOM information became available, however, SAO's analysis assumed a slightly different character; the objectives became those of:

1. Determining whether DARCOM information would have been adequate for several representative airframe and spares contracts.

2. In the event DARCOM information was found to be inadequate, developing a curve that would provide adequate progress payments in 50 percent of the cases, i.e., an "equally likely" curve.

ASSUMPTIONS

The COTCOS analysis was based upon the following assumptions:

1. That government furnished equipment has a negligible effect upon the incurrence of cost.

2. That the reporting of cumulative costs "lags" the actual incurrence of costs; this reporting lag is assumed to increase linearly until it reaches 90 days midway through the contract and to remain constant thereafter for the remaining half of the contract.

3. That a "normal" contract is closed out 90 days after the last delivery is made.

4. That cost incurred in a continuous function, when in reality it is discrete and discontinuous.

5. That the small number of contracts available for analysis is sufficient to provide a basis for sound generalizations about future cases.

CONSTRAINTS

The COTCOS analysis was constrained by the following considerations:

1. A relatively small number of "clean contracts" on which to perform the analysis.

2. Lack of uniformity in the incurrence and reporting of costs.

METHODOLOGY

The methodology for COTCOS consisted first of the manual extraction of cumulative cost incurred values with the corresponding date through which each cost had been accumulated. These costs, with their respective dates, were obtained from the DD 1195 forms for each contract, the standard form for requesting progress payments.

Next, the data were normalized. This was accomplished by dividing each value of cost incurred by the total contract price. Assumption number one underlay this calculation. Also, the elapsed time for each incurred cost was divided by the total contract time. The Boeing-Vertol contract, number 0811, was a bit unusual in that the first cost incurred statement was issued on the day that the contract was signed. This was because work had been in process for twelve months in anticipation of contract finalization. Thus, it was necessary to add twelve months at the beginning of this contract to put this contract on the same basis of comparison with the other contracts. The contract time was considered to begin when the contract was signed, and to end 90 days after the last delivery was made. In order to account for the time lag between the incurrence of a cost and its reporting, this calculation was based upon assumption number two. It is in the computation of the end point that assumption number three comes to bear. Now, with each value of cost incurred expressed as a percentage of total contract cost and each corresponding date of accumulation expressed as a percentage of contract completion, the points were plotted with percent contract completion on the abscissa and percent total contract cost on the ordinate.

After the data had been plotted, a continuous curve was sketched through the points. The curve represented a manual approximation to a curve of best fit. Assumption number four enters at this point, for the data do not comprise a continuous function, but rather a discrete function.

Also, an attempt was made to correlate the delivery schedules with their respective curves of cost incurred. This was done by first normalizing the delivery schedule, that is, the total number of units delivered at any given time was divided by the total number of units to be delivered. This yielded values for the percent of materiel delivered, a quantity analogous to the percent total contract cost. Times of delivery were normalized in the way previously described. The resultant plot was a discontinuous line showing percent total dollar value of materiel delivered versus percent contract completion at which each delivery was made.

When each of the five data sets had been plotted, and a curve had been sketched through each data set, it was then desired to obtain a sort of average, or "equally likely," curve of cost incurred; that is, a curve for which the cost incurred up to any given percent of contract completion time would be equal to or greater than the cost incurred in 50 percent of the contracts during the same percent of contract completion time. In order to construct this "equally likely" curve it was necessary to make assumption number five. Then, the ordinates for the five curves were averaged at 10 percent intervals through a percent contract completion of 100 percent. Then a continuous curve was drawn, connecting the eleven average points.

The next step was to determine whether an analytical expression might be obtained that would provide a good approximation to the "equally likely" curve. The first approach was that of using a computer program for obtaining a polynomial of best fit by employing a "least squares" routine. While the polynomial approach provided an analytical function, it was subsequently determined that a function of the form

$$Y = A\left[1-e^{-BX^2}\right]$$

provides a much more satisfactory approximation to the manually constructed "equally likely" curve. From the conditions of the problem that the above function must satisfy, it was possible to solve for the constants "A" and "B" such that the final function provided an almost perfect reproduction of the manually constructed "equally likely" curve. A discussion of the fitting of the above function to the manual curve can be found in Appendix C.

The last part of the methodology had to do with the development and programming of a scheme for determining the correlation between the "equally likely" curve and the original data. This was done using standard correlation equations and programming techniques.

So far as the DARCOM data were concerned, they came with normalized (percentage) values for contract cost. Also, it was discovered that by normalizing the DARCOM data for a given length contract that it was possible to plot all sets of data on the same curve. The normalization of the contract time values was accomplished as described above.

RESULTS AND DISCUSSION

Figures 1 through 5, page 17 through 21 show the results of the analysis of the five contracts in graphical form. For the purpose of comparison, the five AVSCOM curves are shown with the DOD termination liability curve in Figure 6, page 22. It will be seen that, for the most part, the contract having the greatest percentage of total contract cost for any given percentage of contract completion was Bell airframe contract number 175. At the other extreme, the first 47 percent of Bell airframe contract number 123 had the least percentage of total contract cost for any given percentage of contract completion; for the latter 53 percent of contract completion, Lycoming contract number 0087 had the least percentage of total contract cost for any given percentage of contract completion.

With the three Bell UH-1 contracts, number 175, 200, and 123, the total dollar values were approximately $60\overline{M}$, $43\overline{M}$ and $29\overline{M}$, respectively. Now, comparing the cost incurred curves for these three contracts shows that, for any given percentage of contract completion, the "175" curve always has the greatest percentage of the total cost, "200" the next greatest percentage, with "123" always showing the least percentage of the three. Thus, for these three Bell contracts at least, it is true that the greater the total cost of the contract, the greater the curve showing the percentage of the total cost incurred. At the present time, neither the author nor anyone with whom he has talked can account for this phenomenon. There are not enough Boeing-Vertol (B-V) cases available to determine whether this same phenomenon would be true of B-V contracts.

The data from the "0087" Lycoming engine contract produce a curve that is more nearly linear than any of the other curves; that is the overall change in its slope in less than that for any of the other curves. This indicates that, for this contract, costs were incurred more uniformly than they were for the other contracts. The reason for this is that the engine contract was for the modernization of engines, and it was not, therefore, necessary to order large quantities of material at the beginning of the contract. The other contracts, being manufacturing contracts, required the early purchase of large quantities of material. Thus, the curves for these contracts rise more rapidly during the early stages of contract life than did the curve for the engine. Had the engine contract been for a manufacturing program instead of modernization program, its curve of cost incurred would have risen more sharply in the initial contract stages.

The graphically constructed AVSCOM "equally likely" or average curve of cost incurred is shown with the DOD termination liability curve in Figure 7, page 23. In Figure 8, page 24 the AVSCOM graphical and analytical curves are compared. A correlation coefficient of 0.99 was found between the analytical and graphical curves. Also the correlation between the analytical curve and all five sets of contract data was found to equal 0.92. The Figure 9, page 25 shows the analytical curve as plotted through the five sets of data. The analytical "equally likely" curve of cost incurred is shown with the DOD termination liability curve in Figure 10,page 26. It can be seen from the figure that, for any given value of percent contract completion, the AVSCOM "equally likely" curve is always greater than the DOD curve except, of course, at the end points. These results indicate that, for Army aircraft FMS cases, collecting funds according to the DOD curve would always result in less money in hand than the amount required to defray termination costs. A tabular comparison between DOD values and AVSCOM values as obtained from the equation is shown in Table I, page 28.

While the above results are valid within the aforementioned constraints, it must be borne in mind that a small number of cases does not provide a sound basis for drawing general conclusions. Also, if more cases were available for analysis, the undesirable effect of constraint number 2 would tend to be alleviated.

CONCLUSIONS

From a comparison of the curves shown in Figure 7, it is evident that the DOD termination liability schedule would not provide an adequate payment schedule for Army aircraft contracts. Thus, a different payment schedule is required for Army aircraft contracts than the one recommended by DOD in Reference 1.

Now, according to page 2 of Reference 1, termination liability is defined as the sum of the disbursements, the cash holdback and the incurred costs. This amounts to defining termination liability as being the sum of all of the contractor's incurred costs. This being the case, the AVSCOM average incurred cost curve fulfills the DOD definition for a termination liability curve and can be considered an "equally likely" termination liability curve for Army aircraft contracts.

According to page 3 of Reference 3, a payment is due 90 days in advance of the anticipated expenditure of that payment. Now, if it were desired to know the initial payment required for a given contract, it would first be necessary to divide the 90 days by the total number of contract days. This would yield some percentage of contract completion. Next, one would find that point on the cost incurred curve having the abscissal value just calculated. Then, reading the corresponding ordinal value of the point, one obtains the percentage of the total contract funds that he must have in hand at the inception of the contract.

The results of this study, in order to have greater applicability to future cases, should be modified as required by the results of future contracts. In order to do this, it will be necessary to analyze future cases as they become available for analysis. Such analysis might reveal whether or not a relationship exists between contract price and the rate at which the normalized cost grows. (See page 9 of this report.)

RECOMMENDATIONS

Based upon the foregoing conclusions the following recommendations are made:

1. That the AVSCOM average or "equally likely" curve of Figure 10 be adopted as the basis for reckoning the payments to be made by FMS customers who purchase Army type aircraft.

2. That a computer system be developed for using future contractual reporting information to modify the AVSCOM curve as may be required to make it more descriptive.

REFERENCES

1. USAATAC Systems Analysis Office Report No. 76-039, July 1976, Subject: "Termination Liability Study for FMS Cases."

2. DACA-FAL-L Message, 30 Jul 76, subject: "Costs Included in Payment Schedules for Dependable Undertaking FMS Cases."

3. DRSIL-WS Letter, 22 Jul 76, subject: "Costs Included in Payment Schedules on Dependable Undertaking FMS Cases."

4. DAF Letter, 12 Jul 76, subject: "FMS C-130 Expenditures Forecast."

5. USAILCOM Letter, 12 Mar 76, subject: "Financial Arrangement for FMS Dependable Undertaking Cases."

6. USAILCOM Letter, 12 Feb 76, subject: "Financial Arrangement for FMS Dependable Undertaking Cases."

APPENDIX A - FIGURES

FIG. 1 - % OF TOTAL CONTRACT COST vs % OF CONTRACT COMPLETION

CONTRACT NO. 123

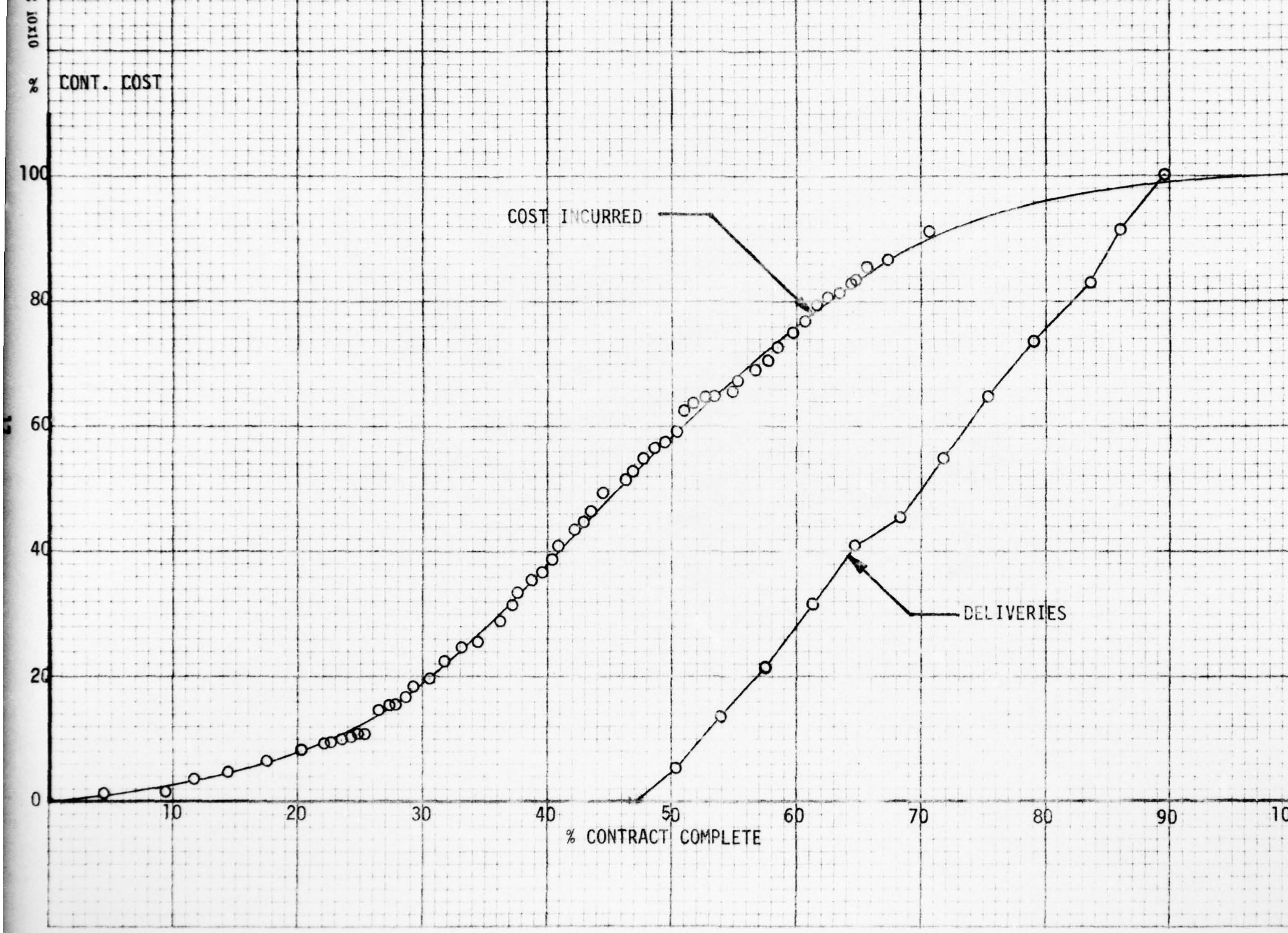

FIG. 2 - % OF TOTAL CONTRACT COST vs % OF CONTRACT COMPLETION
CONTRACT NO. 175

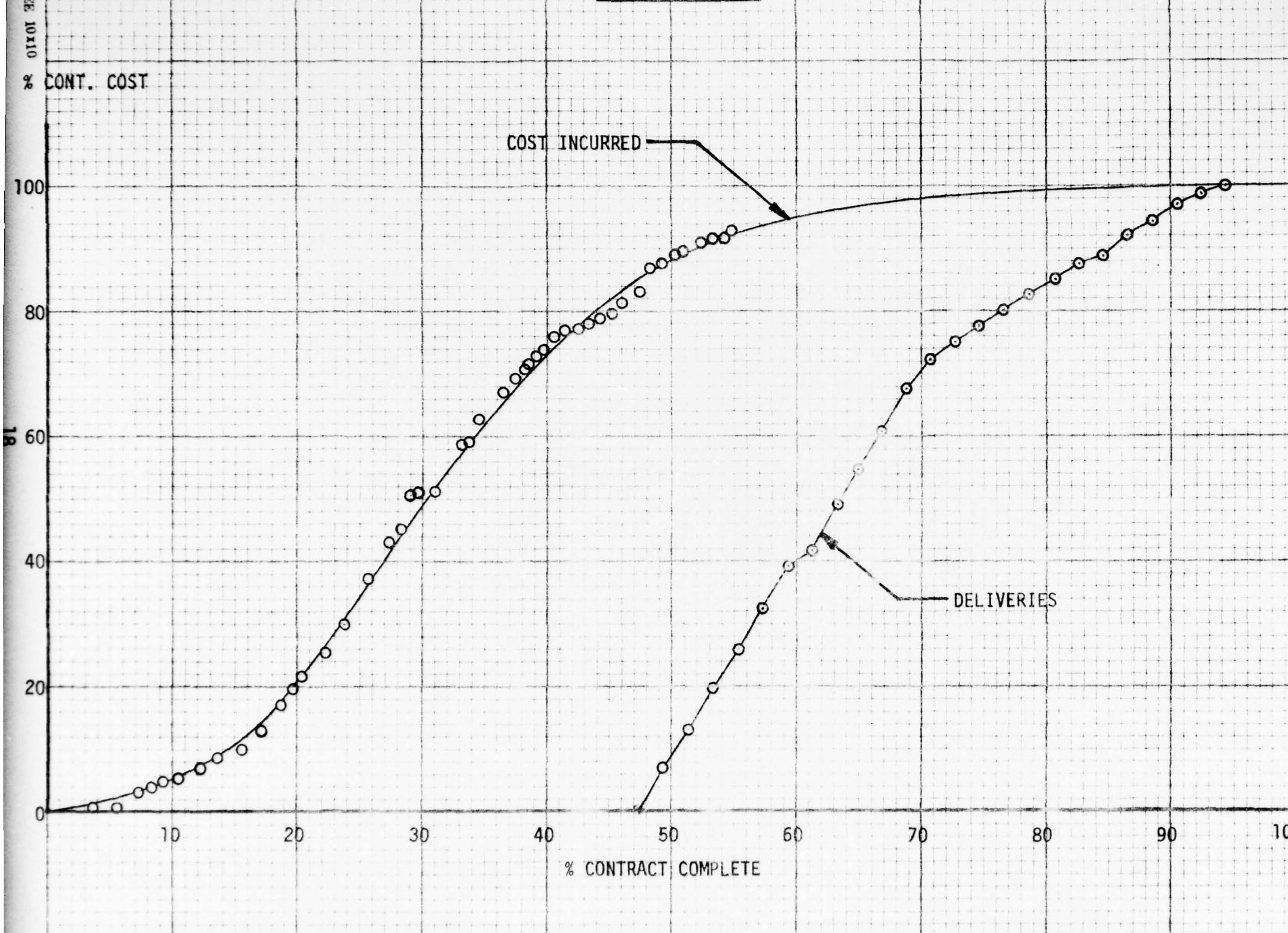

FIG. 3 - % OF TOTAL CONTRACT COST vs % OF CONTRACT COMPLETION

CONTRACT NO. 200

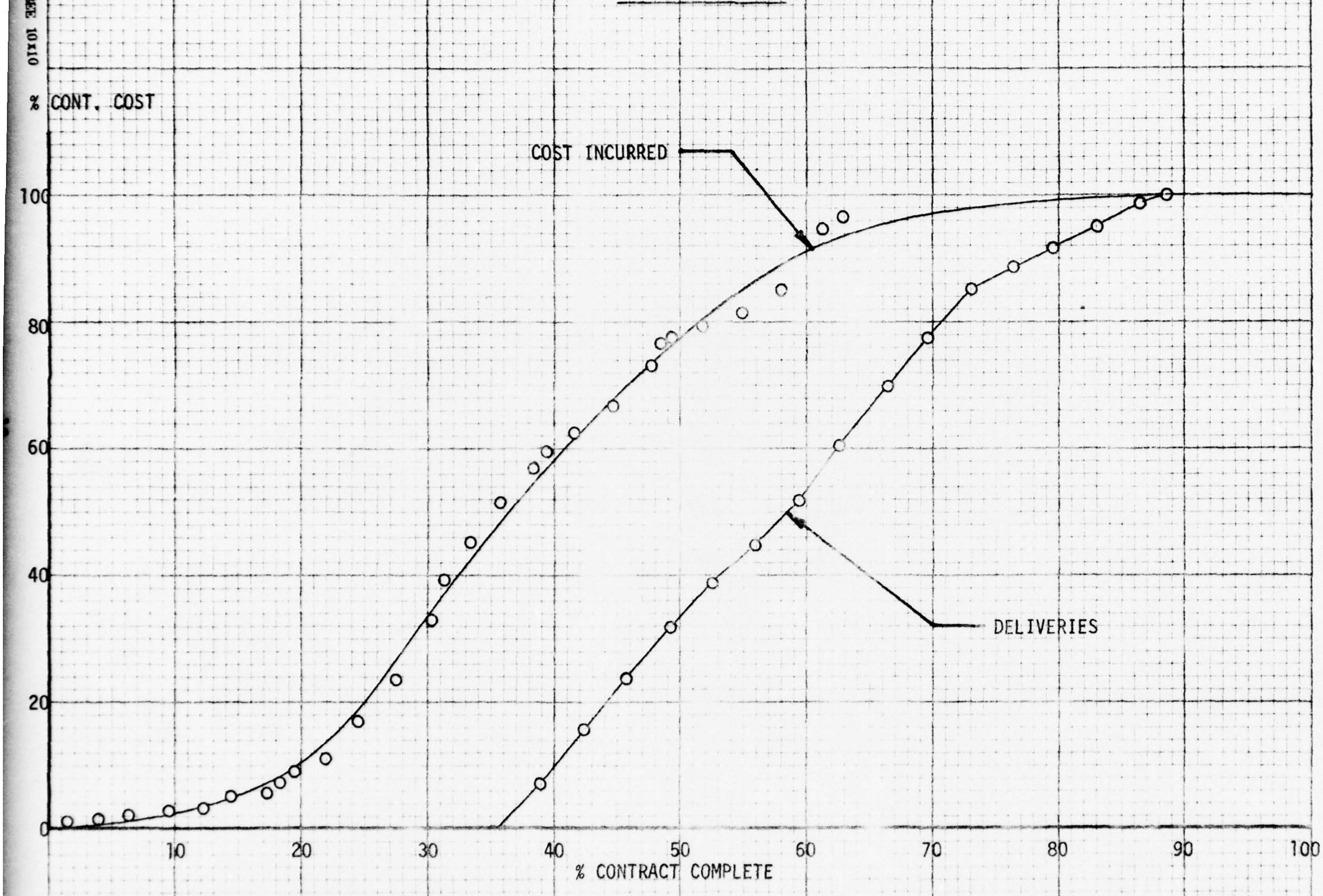

FIG. 4 - % OF TOTAL CONTRACT COST vs % OF CONTRACT COMPLETION
CONTRACT NO. 0811

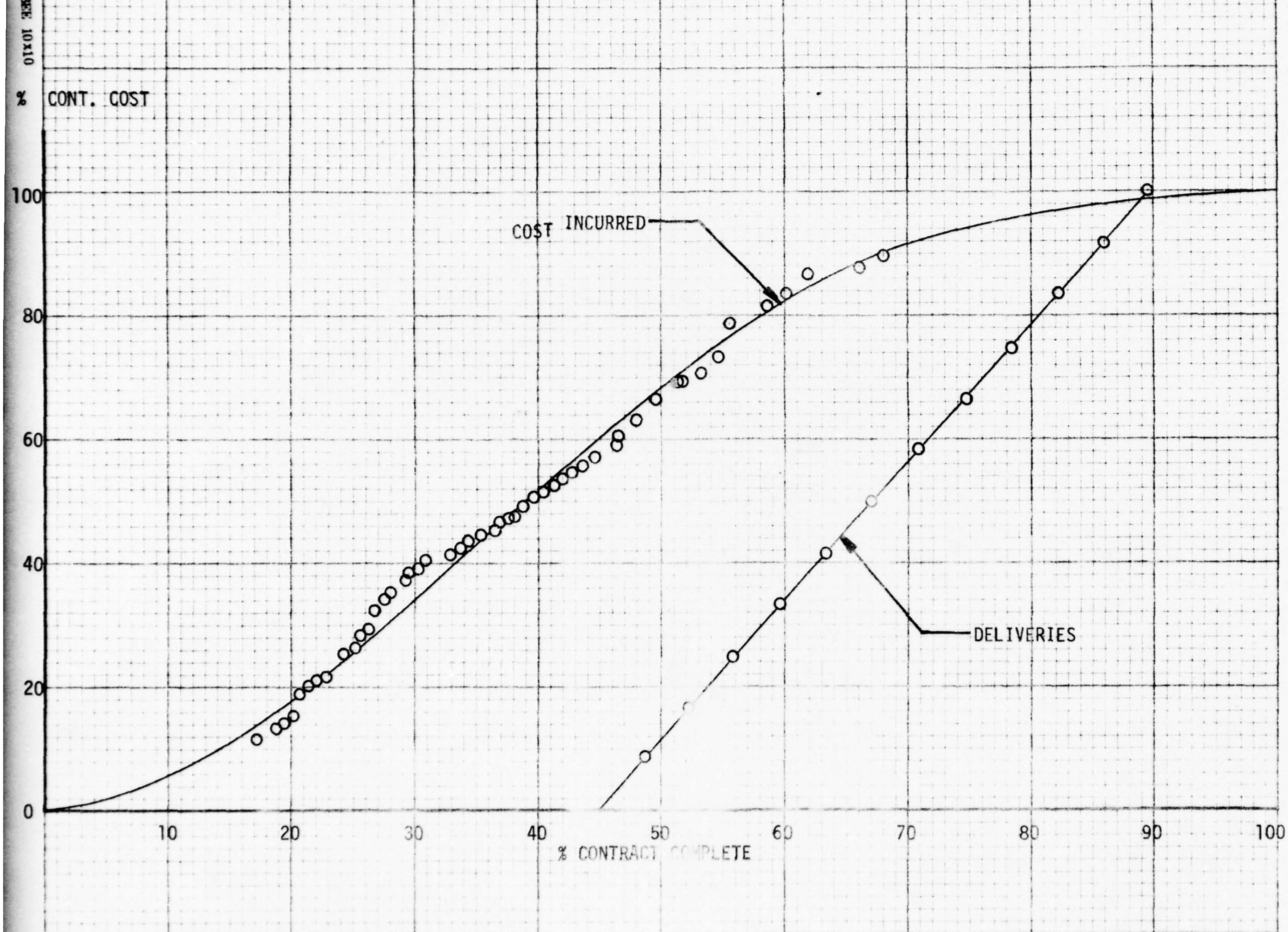

FIG. 5 - % OF TOTAL CONTRACT COST vs % OF CONTRACT COMPLETION

CONTRACT NO. 0087

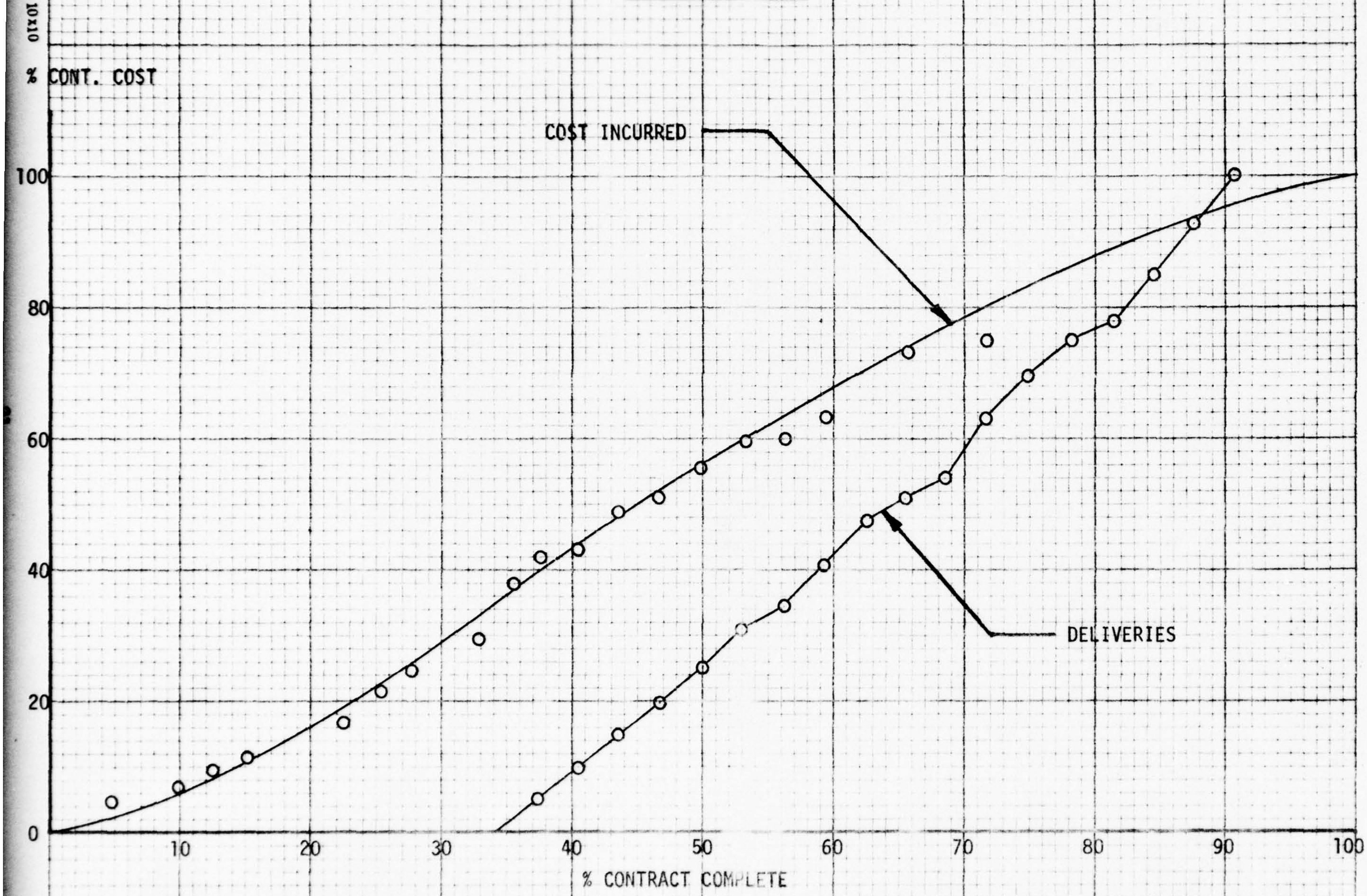

FIG. 6 - % OF TOTAL CONTRACT COST vs % OF CONTRACT COMPLETION
COMPARISON OF CONTRACT CURVES AND DOD CURVE

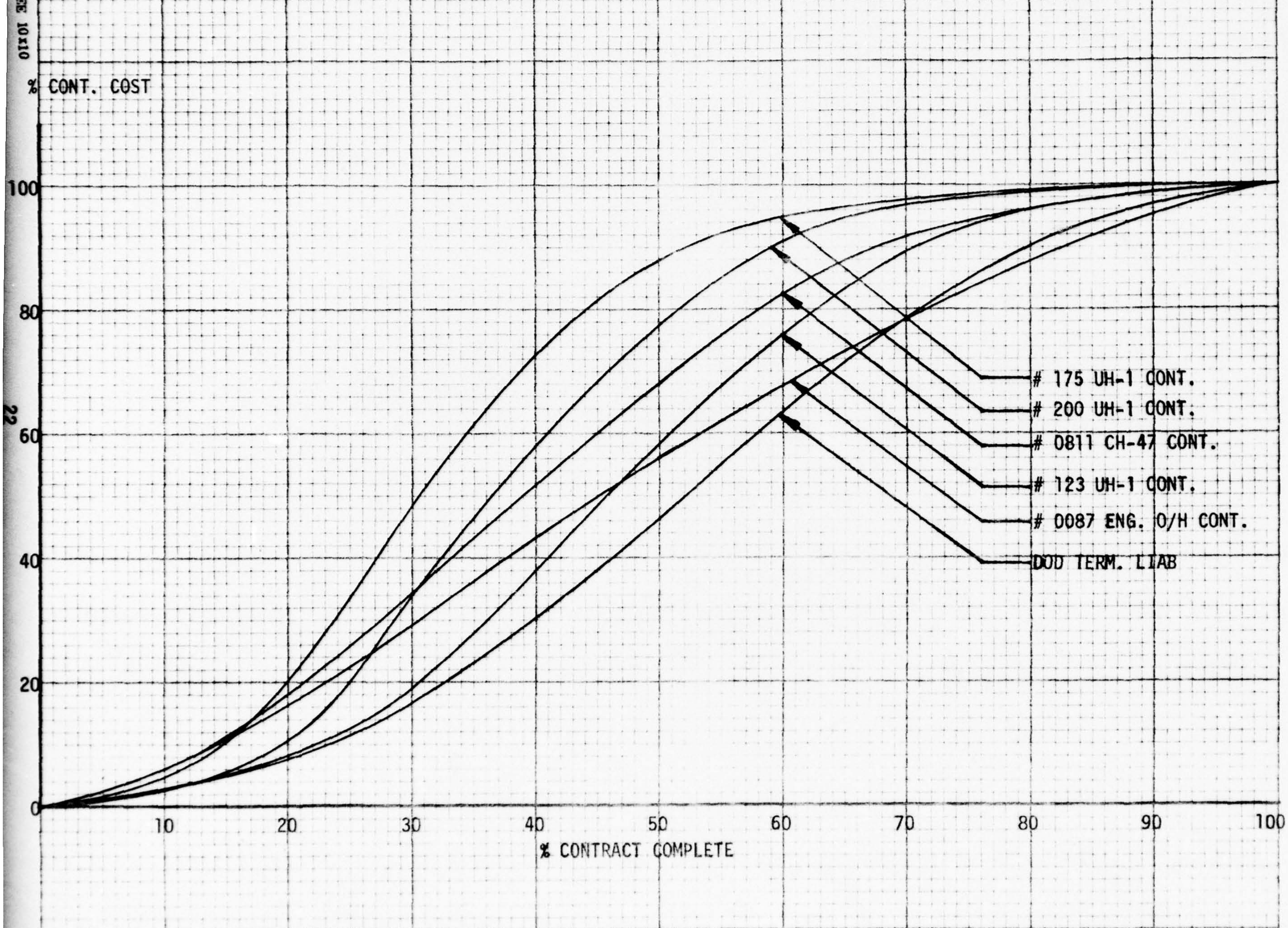

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FIG. 7 - % OF TOTAL CONTRACT COST vs % OF CONTRACT COMPLETION
COMPARISON BETWEEN AVSCOM GRAPHICAL AND DOD CURVES

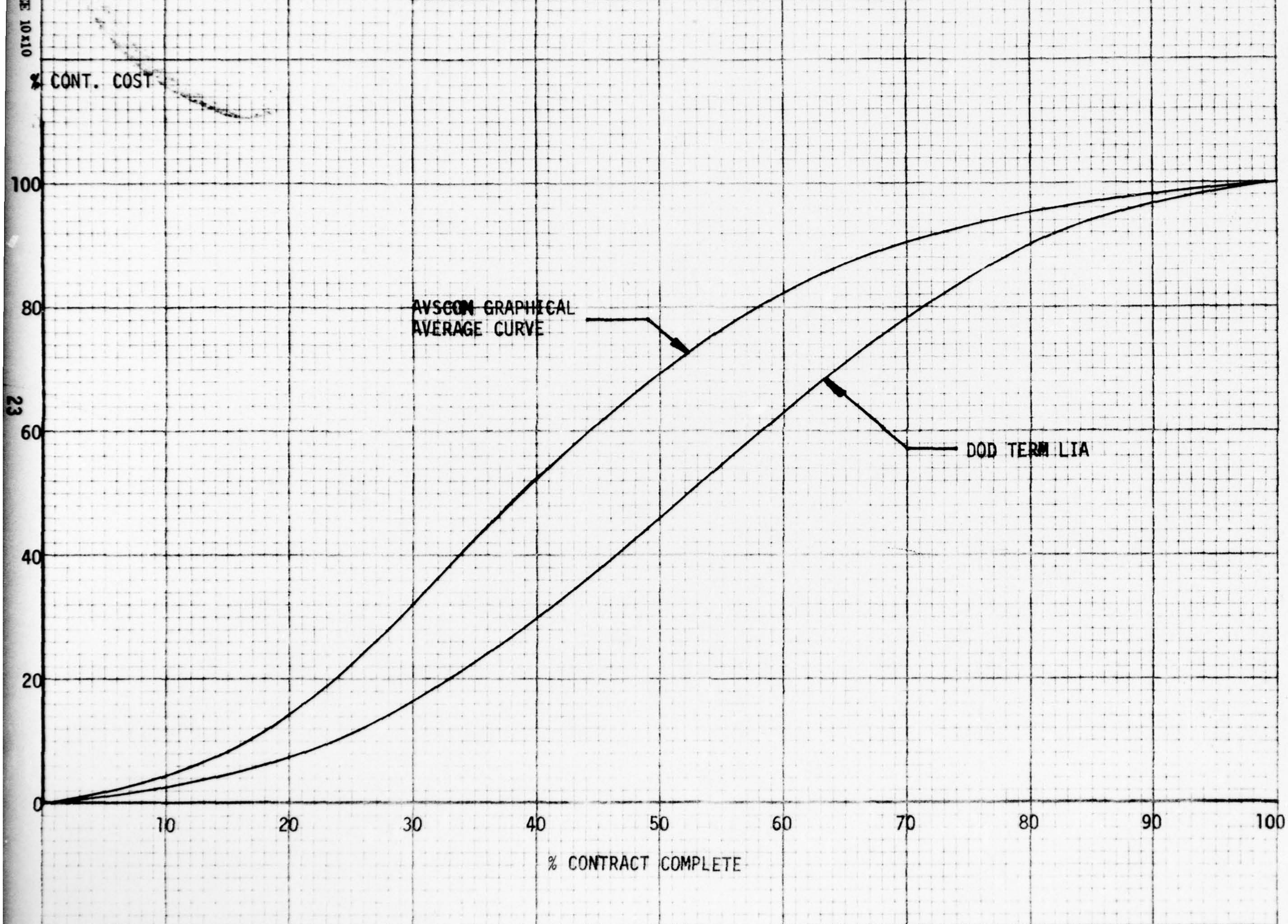


FIG. 8 - % OF TOTAL CONTRACT COST vs % OF CONTRACT COMPLETION
COMPARISON BETWEEN AVSCOM GRAPHICAL AND ANALYTICAL CURVES

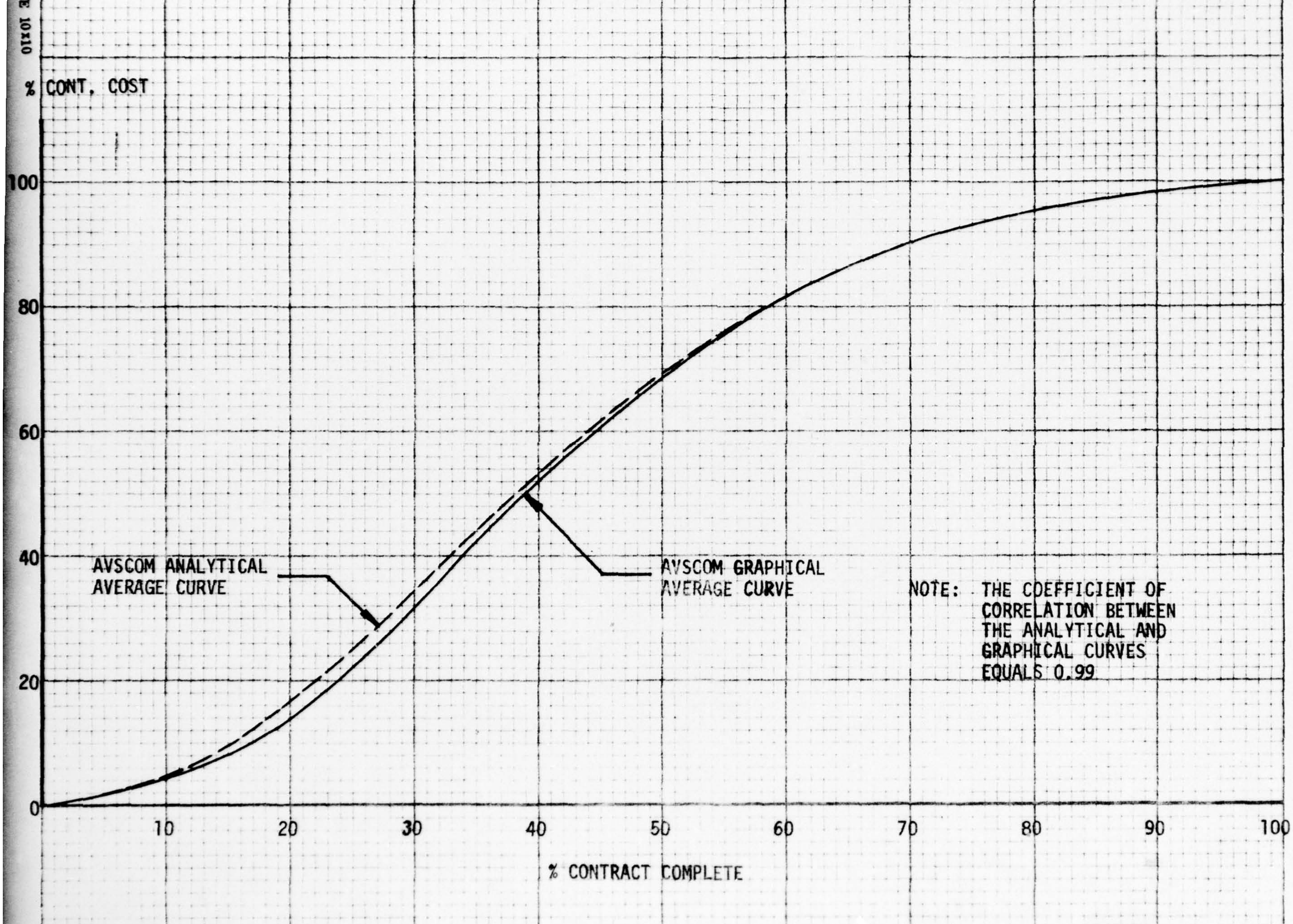


FIG. 9 - % OF TOTAL CONTRACT COST vs % OF CONTRACT COMPLETION. FIT OF AVSCOM AVERAGE CURVE TO THE FIVE SETS OF CONTRACT DATA

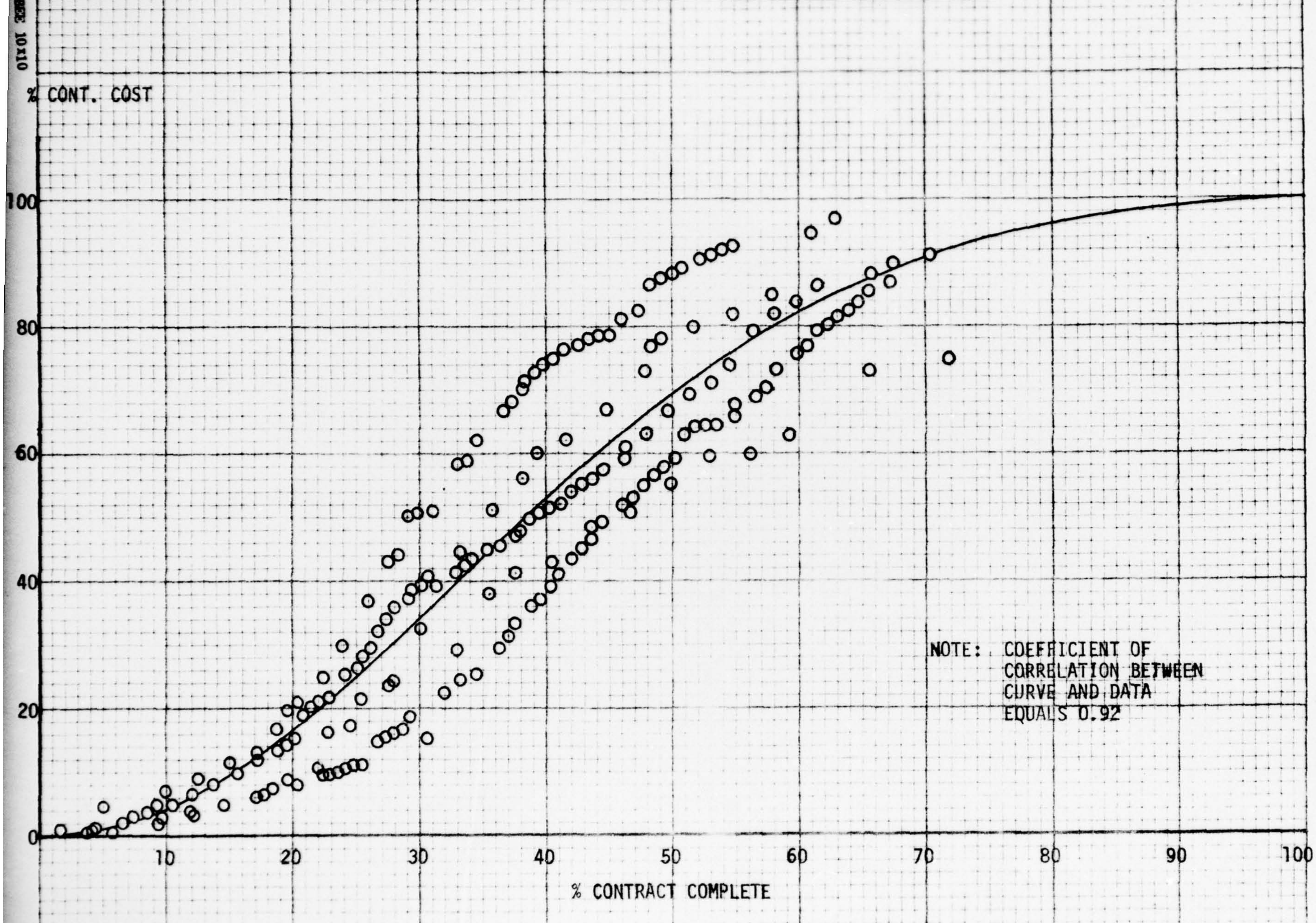
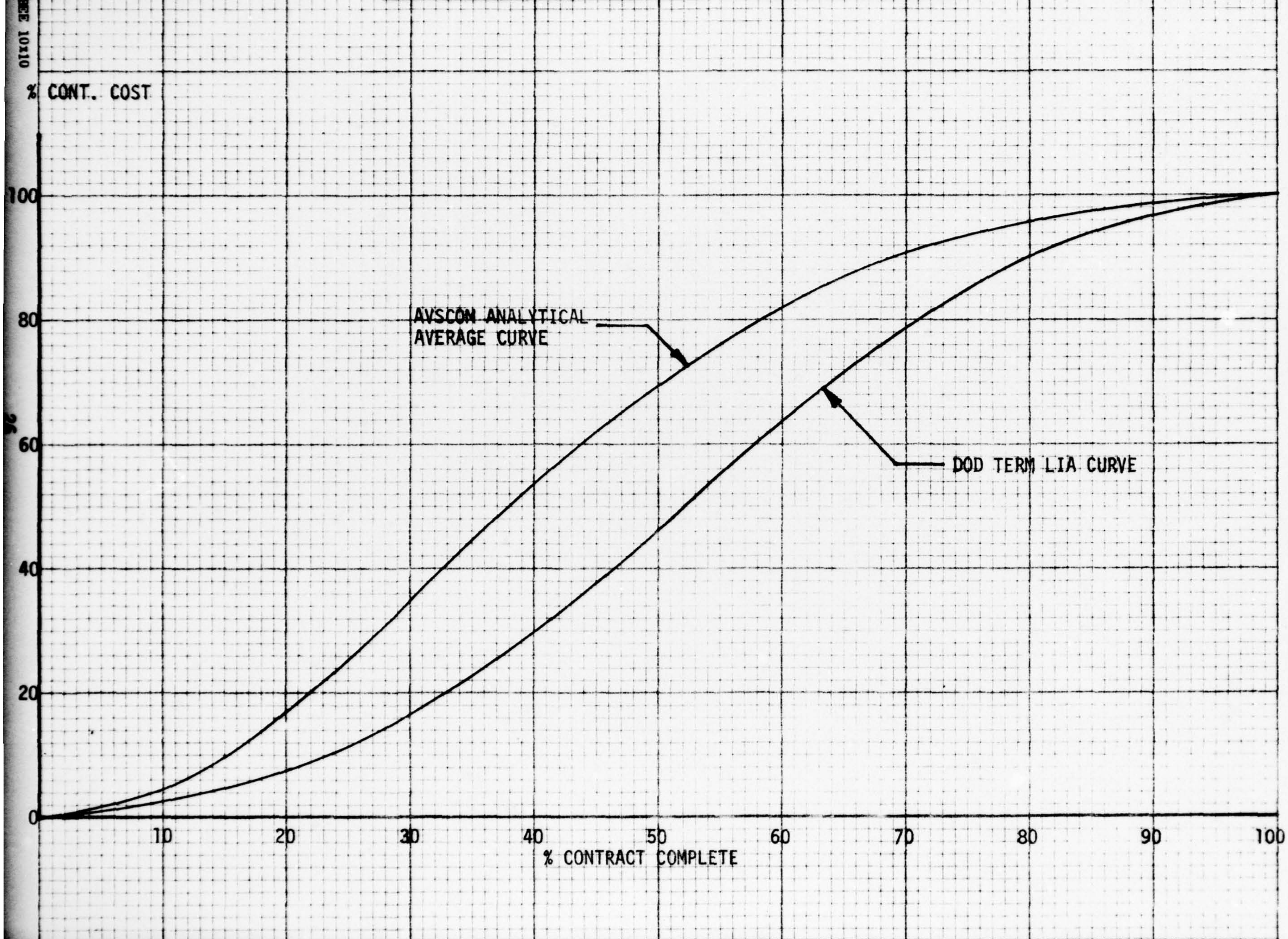


FIG. 10 - % OF TOTAL CONTRACT COST vs % OF CONTRACT COMPLETION
COMPARISON BETWEEN AVSCOM ANALYTICAL CURVE AND DOD CURVE



APPENDIX B - TABLES

TABLE I - PERCENT OF TERMINATION LIABILITY FOR VARIOUS LEADTIMES (AVSCOM)

Lead Time in Months

6		9		12		15	
DOD	AVSCOM	DOD	AVSCOM	DOD	AVSCOM	DOD	AVSCOM
100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
93.33	96.90	91.65	98.36	97.92	98.91	98.78	99.1[illegible]
73.97	88.02	89.64	94.80	93.33	96.90	95.43	97.83
46.10	69.14	69.45	88.02	85.12	93.47	90.71	95.72
20.38	40.51	54.24	76.69	73.97	88.02	82.93	92.56
5.41	12.16	38.56	60.40	60.35	79.99	73.96	88.02
0	0.00	23.73	40.51	46.10	69.14	63.03	81.52
		11.83	20.58	32.25	55.68	51.76	73.82
		3.49	5.59	20.58	40.51	40.42	64.6[illegible]
		0	0.00	11.72	25.31	29.77	52.7[illegible]
				5.41	12.16	20.58	40.51
				1.70	3.18	13.29	28.2[illegible]
				0	0.00	7.69	17.0[illegible]
						3.57	7.95
						1.27	2.05
						0	0.00

18		21		24		27	
DOD	AVSCOM	DOD	AVSCOM	DOD	AVSCOM	DOD	AVSCOM
100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
99.04	99.35	98.12	99.46	99.[illegible]	99.54	99.36	99.50
96.77	98.37	96.25	98.69	97.92	98.91	98.29	99.07
93.33	96.90	94.38	97.60	95.87	98.05	95.77	98.37
88.52	94.81	89.07	96.09	93.33	96.90	94.48	97.43
81.38	91.90	83.76	94.07	89.81	95.40	91.72	96.28
73.96	88.02	78.45	91.41	85.12	93.47	88.32	94.81
64.91	82.98	73.97	88.02	79.76	91.03	83.76	92.97
55.51	76.70	64.48	83.77	73.96	88.02	78.90	90.73
46.10	69.14	55.00	78.62	67.23	84.35	73.97	88.32
36.68	60.40	46.34	72.53	60.35	79.99	67.93	84.79
28.12	50.75	38.67	65.53	53.15	74.93	61.77	81.05
20.58	40.51	31.06	57.74	46.09	69.14	55.51	76.70
14.38	30.26	25.79	49.31	39.00	62.69	49.24	71.79
9.38	20.58	20.58	40.51	32.20	55.68	42.96	66.36
5.41	12.16	13.05	31.70	26.14	48.22	36.68	60.04
2.64	5.59	10.37	23.25	20.58	40.51	30.97	54.05
1.01	1.43	7.69	15.58	15.77	32.80	25.60	47.38
0	0.00	5.44	9.08	11.73	25.31	20.58	40.51
		3.19	4.14	8.30	18.33	16.45	33.65
		0.94	1.05	5.41	12.16	12.72	26.94
		0	0.00	3.21	7.03	9.38	20.58
				1.70	3.18	6.73	14.79
				0.74	0.81	4.48	9.72
				0	0.00	2.64	5.59
						1.52	2.53
						0.74	0.64
						0	0.00

Lead Time in Months

30		33		36		39	
DOD	AVSCOM	DOD	AVSCOM	DOD	AVSCOM	DOD	AVSCOM
100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
99.72	99.65	99.17	99.68	99.83	99.71	98.88	99.74
98.27	99.19	98.33	99.28	99.14	99.35	97.75	99.41
97.08	98.60	97.50	98.77	97.92	98.91	96.62	99.02
95.43	97.85	95.68	98.14	96.77	98.37	95.38	98.54
93.33	96.90	93.85	97.36	95.21	97.70	94.13	97.97
90.71	95.73	92.02	96.40	93.33	96.90	92.88	97.29
87.35	94.30	88.74	95.25	91.33	95.95	90.92	96.48
82.93	92.56	85.47	93.86	88.52	94.81	88.97	95.53
78.57	90.48	82.20	92.21	85.12	93.47	87.02	94.42
73.97	88.02	78.09	90.27	81.53	91.90	83.86	93.13
68.61	85.14	73.97	88.02	77.90	90.09	80.71	91.64
63.03	81.82	68.61	85.42	73.97	88.02	77.56	89.94
57.62	78.06	63.72	82.46	69.45	85.65	73.97	88.02
51.76	73.82	58.83	79.13	64.91	82.98	70.51	85.84
46.10	69.14	53.94	75.42	60.35	79.99	67.15	83.41
40.43	64.04	48.50	71.33	55.65	76.70	63.03	80.71
34.85	58.54	43.07	66.86	50.85	73.08	58.89	77.74
29.77	52.74	37.64	62.07	46.10	69.14	54.75	74.51
24.98	46.70	33.28	56.98	41.37	64.91	50.47	70.99
20.58	40.51	28.93	51.65	36.69	60.40	46.02	67.23
16.69	34.33	24.58	46.13	32.25	55.68	41.94	63.21
13.29	28.26	20.58	40.51	28.13	50.75	37.64	58.98
10.28	22.44	16.94	34.88	24.22	45.67	33.85	54.56
7.69	17.03	13.29	29.34	20.58	40.51	29.77	49.97
5.41	12.16	10.05	23.99	17.2[illegible]	35.37	25.18	45.28
3.57	7.95	8.80	18.94	14.38	30.26	20.58	40.51
2.22	4.56	6.55	14.29	11.72	25.50	16.17	35.75
1.27	2.05	4.94	10.15	9.38	20.58	13.85	31.05
.60	0.52	3.32	6.62	7.27	16.17	11.53	26.43
0	0.00	1.70	3.78	5.39	12.16	9.21	22.01
		1.15	1.70	3.52	8.60	7.61	17.82
		.57	0.43	2.63	5.59	6.01	13.96
		0	0.00	1.70	3.18	4.40	10.45
				1.05	1.43	3.43	7.38
				.51	0.36	2.46	4.79
				0	0.00	1.49	2.72
						.94	1.22
						.45	0.31
						0	0.00

Lead Time in Months

42 DOD	42 AVSCOM	45 DOD	45 AVSCOM	48 DOD	48 AVSCOM	51 DOD	51 AVSCOM
100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
99.06	99.76	99.43	99.78	99.82	99.79	99.78	99.80
98.12	99.46	98.85	99.51	99.60	99.54	99.56	99.57
97.18	99.11	98.27	99.19	98.76	99.25	99.34	99.31
96.25	98.69	97.33	98.81	97.92	98.91	98.31	99.00
95.31	98.19	96.38	98.37	96.90	98.51	97.28	98.64
94.38	97.60	95.43	97.85	95.87	98.05	96.25	98.22
93.33	96.90	93.85	97.24	94.60	97.52	94.99	97.74
89.07	96.09	92.28	96.54	93.33	96.90	93.73	97.20
86.42	95.15	90.71	95.73	91.57	96.20	92.47	96.58
83.76	94.07	88.13	94.81	89.81	95.40	90.76	95.88
81.10	92.83	85.53	93.76	87.47	94.49	89.04	95.09
78.45	91.41	82.93	92.56	85.12	93.47	87.32	94.20
76.21	89.81	79.95	91.21	82.44	92.32	84.67	93.21
73.97	88.02	76.96	89.70	79.76	91.03	82.01	92.10
69.23	86.01	73.97	88.02	76.86	89.60	79.35	90.87
64.48	83.77	70.32	86.14	73.97	88.02	76.66	89.51
59.74	81.31	66.68	84.08	70.60	86.26	73.97	88.02
55.00	78.62	63.03	81.82	67.23	84.35	70.89	86.38
52.04	75.69	59.28	79.36	63.79	82.27	67.59	84.59
49.07	72.53	55.52	76.70	60.35	79.99	64.38	82.64
46.10	69.14	51.76	73.82	56.75	77.55	61.10	80.54
41.06	65.53	47.99	70.75	53.15	74.93	57.99	78.29
36.03	61.73	44.21	67.49	49.63	72.11	54.87	75.87
31.00	57.74	40.43	64.04	46.10	69.14	51.75	73.29
28.49	53.59	36.68	60.40	42.55	66.00	48.25	70.56
25.79	49.31	33.23	56.64	39.00	62.69	44.76	67.68
23.18	44.93	29.77	52.74	35.63	59.25	41.27	64.66
20.58	40.51	26.71	48.73	32.25	55.68	37.98	61.50
16.82	36.09	23.64	44.65	35.30	51.99	34.69	58.21
13.05	31.70	20.58	40.51	26.14	48.22	31.40	54.82
11.71	27.41	17.15	36.39	23.36	44.39	28.50	51.34
10.37	23.25	16.72	32.29	20.58	40.51	25.60	47.76
9.03	19.29	13.29	28.26	18.17	36.64	22.70	44.15
7.69	15.58	11.34	24.33	15.77	32.80	20.58	40.51
6.57	12.16	9.38	20.58	13.75	29.00	18.34	36.87
5.44	9.08	7.69	17.03	11.72	25.30	16.09	33.24
4.32	6.39	6.32	13.71	10.01	21.74	14.16	29.67
3.19	4.14	4.94	10.68	8.30	18.33	12.22	26.17
2.07	2.35	3.57	7.95	6.[illegible]	15.13	10.28	22.77
0.94	1.05	2.64	5.59	5.41	12.16	8.77	19.52
0.44	0.25	1.96	3.62	4.31	9.44	7.26	16.42
0	0.00	1.27	2.05	3.21	7.03	5.75	13.53
		0.83	0.91	2.45	4.94	4.80	10.85
		0.41	0.23	1.70	3.18	3.85	8.42
		0	0.00	1.22	1.80	2.90	6.25
				0.74	0.81	2.30	4.38
				0.38	0.20	1.71	2.82
				0	0.00	1.11	1.60
						0.72	0.71
						0.36	0.18
						0	0.00

Lead Time in Months

		57		60	
DOD	AVSCOM	DOD	AVSCOM	DOD	AVSCOM
100.00	100.00	100.00	100.00	100.00	100.00
*	99.82	99.63	99.83	99.86	99.83
99.36	99.60	99.26	99.63	99.72	99.65
99.04	99.35	98.89	99.40	98.99	99.43
98.29	99.07	98.19	99.13	98.27	99.19
*	98.74	97.49	98.83	97.92	98.91
96.77	98.37	96.79	98.49	97.08	98.60
*	97.94	95.80	98.10	96.26	98.24
94.48	97.45	94.81	97.66	95.43	97.85
93.33	96.90	93.82	97.17	94.38	97.40
91.72	96.28	92.42	96.62	93.33	96.90
*	95.59	91.01	96.00	92.02	96.35
88.52	94.81	89.61	95.31	90.71	95.73
*	93.94	88.31	94.54	89.03	95.05
83.76	92.97	89.01	93.69	87.35	94.30
81.38	91.90	85.71	92.75	85.12	93.47
78.90	90.73	82.55	91.73	82.93	92.56
*	89.43	79.40	90.60	80.75	91.56
73.97	88.02	76.25	89.36	78.57	90.48
*	86.46	73.97	88.02	76.27	89.29
67.93	84.79	69.86	86.55	73.97	88.02
64.91	82.98	65.75	84.98	71.29	86.63
61.77	81.03	63.93	83.27	68.61	85.14
*	78.93	62.12	81.45	65.82	83.54
55.51	76.70	60.31	79.49	63.03	81.82
*	74.31	56.99	77.42	60.35	79.99
49.24	71.79	53.67	75.21	57.62	78.06
46.10	69.14	50.35	72.87	54.69	76.00
42.96	66.36	48.18	70.42	51.76	73.82
*	63.45	46.00	67.83	48.93	71.54
36.68	60.40	42.88	65.14	46.10	69.14
*	57.27	39.75	62.33	43.27	66.63
30.97	54.05	36.67	59.43	40.43	64.04
28.12	50.75	33.55	56.44	37.64	61.33
25.60	47.38	30.69	53.36	34.85	58.74
*	43.97	27.82	50.22	32.25	55.68
20.58	40.51	24.95	47.01	29.77	52.74
*	47.07	22.77	43.78	27.38	49.73
16.45	33.65	20.58	40.31	24.98	46.70
14.38	30.26	18.65	37.26	22.70	43.62
12.72	26.94	16.87	34.00	20.58	40.51
*	23.70	15.08	30.79	18.64	37.42
9.38	20.58	13.29	27.64	16.69	34.33
*	17.60	11.70	24.54	14.90	31.26
6.73	14.79	10.11	21.56	13.29	28.26
5.41	12.16	8.51	18.68	11.72	25.30
4.48	9.72	7.65	15.95	10.28	24.14
*	7.53	6.78	13.39	8.40	19.68
2.64	5.59	5.91	10.98	7.69	17.03
*	3.92	5.02	8.78	6.55	14.51
1.52	2.53	4.14	6.79	5.41	12.16
1.43	1.43	3.25	5.04	4.49	9.96
0.74	0.64	2.64	3.52	3.57	7.95
*	0.16	2.03	2.27	2.90	6.15
0	0.00	1.42	1.28	2.22	4.56
		0.79	0.57	1.70	3.18
		0.35	0.14	1.27	2.05
		0	0.00	0.94	1.16
				0.60	0.57
				0.31	0.13
				0	0.00

APPENDIX C -

DERIVATION OF EQUATION FOR "EQUALLY LIKELY" CURVE

APPENDIX C

DERIVATION OF EQUATION FOR AVERAGE OR "EQUALLY LIKELY" CURVE

Upon close inspection of the average or "equally likely" curve shown in Figure 7, it was noted that the shape of the curve is the same as the shape of the curve described by the function.

$$Y = A\left[1-e^{-BX^2}\right] \qquad (1)$$

Now, in the above expression, the independent variable is "X" and the dependent variable "Y." For the average curve, the independent variable is percent contract completion and the dependent variable percent contract cost. Consequently, we shall allow

X - percent contract completion

Y - percent contract cost

Since percent contract completion and percent contract cost must be positive, the following discussion will only consider positive values of "X" and "Y." From Figure 7 it will be seen that two of the points through which the average curve goes are the (0,0) and the (100,100) points. The first point indicates that no contract costs are incurred at the time the contract begins. The second point indicates that all of the contract costs must have been incurred when a contract has been completed. Substituting

$$X = 0$$

into equation (1) we find that

$$Y = 0$$

also. Thus the whole family of curves described by equation (1) goes through the (0,0) point, and it is not necessary to choose any certain values of the constants, "A" and "B" in order to fit the equation through the (0,0) point. Since it was not necessary to solve for either constant in order to make go through the (0,0) point, there are still two undetermined constants and equation (1) may be fit through two additional points on the graphically constructed average curve. Thus, equation (1) will pass through a total of three of the points on the graphical curve.

For the two additional points, we choose "X" values of 50 and 100 percent; the corresponding "Y" values are 69.5 and 100 percent, respectively.

The next step is solving equation (1) for "B." Dividing both sides by "A" yields

$$\frac{Y}{A} = 1-e^{-BX^2} \tag{2}$$

adding negative one to both sides of equation (2) gives

$$\frac{Y}{A} - 1 = -e^{-BX^2} \tag{3}$$

If equation (3) is multiplied by negative one, the result is

$$1 - \frac{Y}{A} = e^{-BX^2} \tag{4}$$

If the natural logarithm of both sides of equation (4) is taken,

$$\left[Ln \; 1 - \frac{Y}{A}\right] = -BX^2 \tag{5}$$

is obtained.

Substituting the point values (50.0, 69.5) and (100.0, 100.0) into equation (5) gives the two equations

$$LN\left[1 - \frac{69.5}{A}\right] = -B\,(50.0)^2$$

and (6-a)

$$LN\left[1 - \frac{100.0}{A}\right] = -B\,(100.0)^2$$

or

$$LN\left[1 - \frac{69.5}{A}\right] = -2,500B$$

(6-b)

and

$$LN\left[1 - \frac{100.0}{A}\right] = -10,000B$$

Solving the two equations for "B," and then setting them equal, yields

$$LN\left[1 - \frac{100.0}{A}\right] = 4LN\left[1 - \frac{69.5}{A}\right] \qquad (7)$$

Eq. (7) cannot be solved by standard algebraic techniques, so it is necessary to employ an iterative technique. Solving equation (7) iteratively gives

$$A = 100.9511$$

The corresponding value of "B" is obtained by substituting the above value of "A" into either of equations (6-b). This yields

$$B = 4.6648 \times 10^{-4}$$

In order to make equation (1) more convenient for use, we round off the value of "A" so that

$$A = 101$$

This gives a corresponding value of

$$B = 4.6152 \times 10^{-4}$$

Substituting the "A" and "B" values into equation (1) gives a result of

$$Y = 101 \left[1-e^{-0.00046152X^2}\right] \tag{8}$$

A comparison between the average curve and the plot of equation (8) is shown in Figure 8. It will be seen that the plot of equation (8) provides an excellent approximation to the average curve.

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